RESEARCH MANAGEMENT

A PUBLICATION OF THE
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ABOUT THIS ISSUE

The Spring 1960 meeting of the Institute had a session devoted to the administration of overseas industrial research. One of the papers presented on that occasion, "The Management Policy of the Philips Research Laboratory," appeared in the Winter 1960 issue of *Research Management*. We now publish a second paper "Chemical Research in Germany." The author is Dr. Otto Horn who presents a lucid account of the rehabilitation of the industry from the rubble of World War II. He writes with first-hand experience about a people determined to regain a position of technological eminence, at whatever cost in privation and austere living conditions, by devotion to its tradition of education, training, and research. The assistance provided by outside organizations and by German societies formed or re-established since the war is also described. Dr. Horn heads the research organization of Farbwerke Hoachst AG.

Far more than in modern times, scientists of past years performed their work on an individualistic basis. The great creative achievements of some tended to set apart the entire class from others and one of its distinguishing marks was that of individualism. That quality is indispensable today as ever. Can it be nurtured in a group environment? The success of organized research has demonstrated that it can. This is accomplished, however, not without effort but through conscious application of the knowledge that the aims of the scientist differ in degree but not in kind from the aims of all men. Our second article, "The Research Director And His People," shows how to achieve the satisfaction of individual aspirations in the environment of the modern labora-

tory. The author is P. J. Keating, Jr., Manager, Commercial Development-Products at the Texaco Research Center.

The quickening tempo of industrial research has shortened the time lag between basic discovery and practical exploitation. Indeed, in some advanced fields, commercial developments tread at the heels of basic science and on occasion must pause for want of progress in the latter. Universities and other centers of learning have always realized that an indispensable element of progress is the prompt publication of the results of research. Industrial organizations have often been reluctant to follow that example. In our third article, "Why Publish Scientific Results from Industry?," Dr. Schmitt of the General Electric Company demonstrates powerfully that such reluctance is wrong on general principles and on specific counts. The author is the manager of the Physical Metallurgy Section, Metallurgy and Ceramics Research Department.

In this issue, we publish the third Proceedings of the IRI Study Group Conferences; this one on "Selection and Placement of Research Personnel." The two sessions on that topic were led by James A. Bralley, Director of Chemical Research, A. E. Staley Manufacturing Company, and D. Lorin Schoene, Assistant Director of Research and Development, U. S. Rubber Company. Both sessions were characterized by lively discussion on the part of well-informed personnel. The observations and conclusions which were developed are here recorded as a staff report.

The written policy of a company provides a clue to the thinking of its top management in the subject the document covers. When that written policy is concerned with the research and development philosophy of an organization in a research-based industry, the document is sure to have more than transient importance. Particularly is this true when the company whose research philosophy is expounded has a history of R&D expenditures of $200,000 in 1948 and $31 million eleven years later. Such is the case with Texas Instruments Incorporated. Our last article, "Research Management at Texas Instruments," is the

substance of the presentation made by R. W. Olson, Vice President for Research and Engineering of that company at the Spring 1960 meeting of the Institute.

CHEMICAL RESEARCH IN GERMANY

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Scientific and technical research has gained ever-increasing importance in the last two centuries. Nations, such as England, France, Germany, Russia, and the U.S.A., have made valuable contributions to this development by a free exchange of views as well as of research workers. A hundred years ago, young people studied the natural sciences, that is, the whole field of chemistry, physics, geology and other subjects. Today, they study either chemistry or physics or geology and it looks as if in a hundred years they will be even more specialized and study organic, physical, technical, or nuclear chemistry. One may regret this development, but the vast quantity of material leaves no other choice. What chemist today would claim to have mastered the whole field of chemistry?

Chemical science is relatively young, and the chemical industry is one of the youngest branches of world industry. However, its rate of development has been very much faster than that

* Otto Horn was born in Germany and received his education there. After completing work for his doctorate he began his career at the Kaiser-Wilhelm Institute for Coal Research. Subsequently, he worked at the synthesis of aliphatic compounds, for I. G. Farbenindustrie. He was active in the petro-chemical field at the Farbwerke Hoechst AG. where he was appointed director of research in 1953. Four years later he was designated head of the research management of Farbwerke Hoechst. He also heads the Foreign Relations Department of that company.

of other industries, as may be seen from Figure 1. One reason for the rapid growth is that the chemical industry supplies a great many other industries including new enterprises with synthetic raw

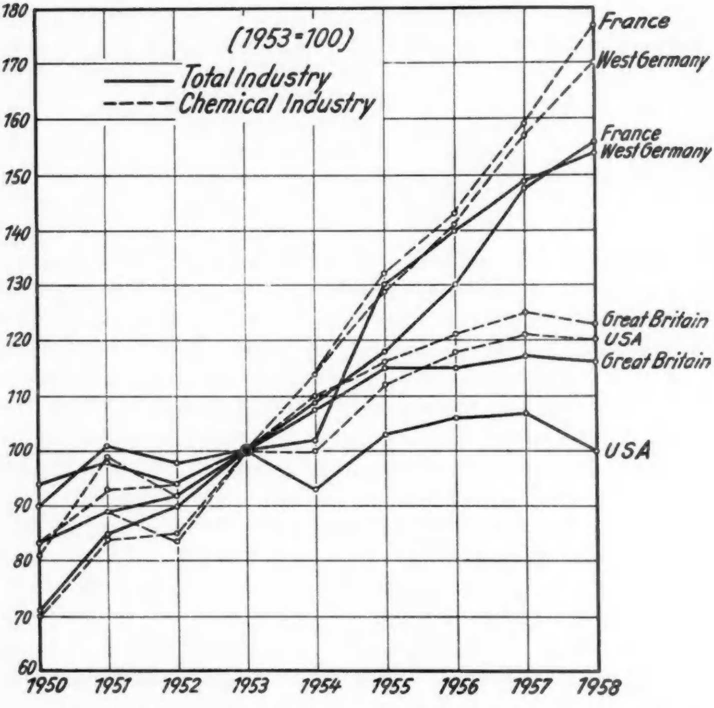

Fig. 1. Development of the chemical industry compared with the total industrial development. (Data from Organization for European Economic Cooperation, September 1960.)

materials for specific applications. This has been made possible only after considerable scientific research.

For instance, European industrialization and the rapid development of technical processes which began in the second half

of the last century were made possible only because vital scientific knowledge had first been accumulated. Or again, when technical reconstruction began in Germany after the last war, it was accomplished so quickly only because it could draw on scientific knowledge that had not been exploited during or before the war.

The prerequisite to technological progress is that the state and the economy take a positive attitude towards research. Industry recognized the value of scientific research at an early date. It is a matter of some satisfaction that repeated appeals for state aid have now been successful in Germany.

Expenditure on research and science in Germany amounted to 2.8 billion DM in 1959—or, for the first time, more than 1% of the national income (which may be estimated at 244.4 billion DM). Table I indicates how this research expenditure was incurred. It is remarkable that the research expenditure by the

TABLE I
Research Expenditure in Germany

	DM, million			
	1957	1958	1959	
Federal Republic and the Länder	1,028	1,332	1,608	
Industry	900	995	1,100	(estimated)
Community research of trade and industry	42	60	70	"
Gifts	49	51	55	"
Total	2,019	2,438	2,833	

Federal Republic increased from DM 100 million in 1955 to 570 million at present. This figure does not include research done by government institutions or atomic research. It has taken a long time for the state to realize that research is a necessary condition of a prosperous economy, a fact that elsewhere, for example in the U.S.A., was generally known long ago.

The chemical industry, however, realized early that it could prosper only on a sound scientific basis. Its tradition of research

is responsible for the fact that today it achieves 40–50% of its sales with products developed since 1948.

Formerly, the word research meant everything that served to increase our knowledge. Today, research is divided into fundamental and development work. In Germany, as in most other countries, fundamental research started at the universities. The close connection between research and teaching was a characteristic and the basis of all German research, especially so in the chemical field. As the importance of research grew, university institutes proved inadequate, and further research institutes were established. Above all, German industry very early recognized the necessity for having good research laboratories of its own.

There are today five types of research institutes in Germany: (*1*) university institutes, (*2*) state institutes, (*3*) institutes of scientific societies, (*4*) commercial research institutes (Battelle), and (*5*) industrial laboratories of trade associations and of independent companies. This development is closely associated with the change of research from creative individual accomplishment to joint or group effort. Today, as before, the young generation in Germany receives its scientific and technical education at the universities and technical colleges. Familiarity with matter, mastery of its vagaries, and evaluation and confirmation by practical experiment on what has been learned have remained the principal feature of chemical training from Liebig's times to this day. Universities primarily serve the purpose of education and secondarily that of research, the teachers are absolutely free and independent in their research work, and their results are published in scientific literature for the benefit of all. Chemical research at German universities is concerned first and foremost with problems of basic research; applied research is secondary, although no clear delineation is possible.

After graduating from high school, the young student begins his chemical study, either at a university or a technical college, attending lectures on chemistry, physics, and physical chemistry and receiving practical instruction in the laboratory. After practical instruction in analytical chemistry, inorganic preparative work,

physics, and physical chemistry, complemented by lectures, the student takes the intermediate examination for our degree equivalent of the B.S., namely the "diploma chemist." This takes about five to six terms. The intermediate examination is followed by a further four to five terms of practical work in preparative, organic, and physical chemistry, followed by a thesis. After this has been approved, and after an examination in chemistry, physical chemistry, and physics, the student is awarded the title of "diploma chemist." In most cases, he then tries for his doctorate after another four to five terms of study. A student, therefore, usually completes his study after sixteen to eighteen terms, unless he wishes to perfect his training by working as an assistant. About 5% of the students stay at the university as teachers and 5% as assistants, while about 50% join large-scale industry, 15% go into medium sized concerns, and about 5% join smaller companies. In 1957, 645 of Germany's chemistry students finished their training by qualifying for a doctor's degree; only 56 entered industry without having such a degree. In 1958 the former figure was 560, and in 1959 it was 612.

In the years immediately after the war, the activity of the German university institutes was hampered by damage to buildings, losses of equipment and books, and insufficient funds. Fortunately, however, the results of research do not depend only on the money spent. The sense of duty of the university teachers and the enthusiasm of the students just released from the armed forces (who frequently aided in rebuilding their institutes) overcame these postwar difficulties. There can be no doubt that the standards in the German universities again match those of their foreign counterparts the major difficulties having been overcome. Donations and other help from many sides have contributed greatly. But more about this later.

In many cases industry has made agreements with university professors to support their work by granting financial subsidies, which are often used to pay for an assistant, and by making chemicals and apparatus available. But in these cases, too, the university teachers are free to choose the subjects of their work, the only

stipulation being that they first release the results to the sponsor.

The history of the German chemical industry is rich in examples that show how greatly it profited from the work of the universities by applying their findings in its own laboratories, even if it was necessary at times to re-examine the work from technical standpoints. Out of Hoechst's range of products, I would only mention the pharmaceutical Pyramidon, which is based on the work on antipyrin by Knoll of Jena, the diphtheria and other sera based on von Behring's efforts, and, more recently, Hostalen, Hoechst's low-pressure polyethylene based on the Ziegler patents. It is also quite common for industry to invite professors to lecture at its plants on industrial and scientific problems which are then discussed.

I wish to emphasize that although very friendly relations exist between industry and the universities, there is no question of the latter being dependent. The consultant who regularly visits a company to discuss its research work is unknown in Germany. The independence of research and teaching is jealously maintained.

The total number of university students in West Germany is about 130,000, of whom 22,000 are studying natural science; 68,000 are students of arts, classics, and law; 16,000 are medical students; and 24,000 are students of technology, architecture, engineering, and other fields.

Let me say a few words about the problem of recruitment in the German chemical profession. At the West German universities, there are at present about 7,500 students of chemistry. Since in Germany the examination for a doctor's degree is considered the conclusion of the study of chemistry, and since fourteen terms should be sufficient to obtain that degree, although 18 terms are still very often required, about 700–800 chemists should be expected to leave the universities every year. In fact, according to statistical data, 645 chemists took a doctor's degree in 1957, and 560 in 1958, and all of them found jobs easily. The number of new students at the universities, however, is decreasing, which is probably due to the length of the training and the high costs.

Since the number of graduates in the chemical industry increases 5–7% each year, unemployment is, for the time being, not to be feared. On the contrary, it should be considered whether the newcomers should not be employed in a more rational way, with more recruits from technical schools being used to reduce the work of the chemists. In the U.S.A., a good solution seems to be provided by high school graduates who have received a very specialized training, for instance in infrared spectroscopy, mass spectroscopy, and other skills.

The *state institutes* serve more particular purposes. The number of these research institutes is not very large. They include the Chemotechnical Government Institute in Brunswick and the Government Testing Stations in Berlin-Dahlem, Darmstadt and Karlsruhe. Apart from investigating basic research problems, their main task is to carry out tests and provide testimonials for the government and other parties. The chemical departments of the various Agricultural Testing and Research Institutes, of the Institutes for Moor Management and for Dairy Farming, of the Government Research Institute for Preservation of Foodstuffs in Karlsruhe and other cities are similar institutions. The foodstuff-testing laboratories of the larger towns and districts may, in a sense, also be counted among the government laboratories, since their results benefit the nation as a whole and they are subsidized by the government.

A special position is occupied by the institutes of the *Max Planck Society* for the Promotion of Sciences. These institutes are financed mainly by the government but are also supported by business associations and industry. Their sole task is research, chiefly fundamental research, and there is no obligation to provide instruction. Most of the 42 institutes under the care of the Max Planck Society specialize in certain fields of work such as metal, iron, silicate and coal research, biochemistry, physiology. The directors are absolutely free and independent in their choice of problem. The institutes are financed both from regular contributions and donations. Results of their research are published

in scientific literature and thus made generally available. Any patents are administered by a special organization which releases them to interested parties upon payment of a license fee. This is, however, not a frequent occurrence since fundamental research constitutes the major work. The world-wide reputation of the Max Planck Institutes provides testimony of the quality of the work performed.

The industrial laboratories comprise not only the factory laboratories proper but also the laboratories maintained by trade associations. Examples of the latter are: the Institutes of the Fermentation Industry in Berlin, the Institute for Tobacco Research at Forchheim, the Institute of The Sugar Industry, the Institute for Starch Manufacture and that for leather research in Munich, the Institute for Textile Research in Krefeld, and that for paints in Stuttgart, the Plastics Institute at Darmstadt, and others. These are joint enterprises with very close relations maintained between the laboratories and industry, both with respect to the problems chosen and the exploitation of results. Companies submit problems to these institutes, but the director of the institute can also initiate work at his discretion on problems germane to the industry concerned. The laboratories, several of which are associated with a university, work on fundamental research problems as well as process development, which requires close contact with manufacturers. Financing is accomplished mainly by a levy upon member companies which may be graduated according to sales volume. A board of trustees consisting of representatives of the government, trade, and industry, assists and advises the director of the institute, which again ensures close cooperation between all the parties concerned. The results are made available to the companies financing the institution; most of the results are also published.

Commercial research companies are new in Germany and they have come to us from the U.S.A. There is at present only one of this kind, the Battelle Institute in Frankfurt, which conducts research for medium and small concerns that do not maintain labo-

ratories of their own. In 1958, the Battelle Institute in Frankfurt concluded research assignments totaling over 7 million DM, a considerable achievement after only 5 years of activity. The interest taken in this institute is great. Its services are used also by several large companies especially where fringe problems are involved.

The laboratories of the chemical industry are, of course, concerned primarily with work likely to yield practical results. Realizing the particular importance of research in the chemical industry, companies have equipped their laboratories generously with up-to-date aids and equipment. Apart from technically promising scientific problems, those of a more fundamental character are also investigated, particularly if they are likely to contribute to the solution of the former. Indeed, it was just this twin aspect of its laboratory work that enabled the German chemical industry to score such remarkable successes in the past. A true scientist cannot, and should not, be prevented from exploring the background to his development work, although, of course, he should not allow himself to become sidetracked. All research work in an industrial laboratory would be in jeopardy if it could not be practically exploited. Therefore, all big chemical factories producing dyestuffs have experimental dye houses and textile-finishing plants; if they manufacture plastics, they need paint, varnish, and lacquer laboratories as well as development laboratories for plastics. The pharmaceutical chemical factories require pharmacological, parasitological, and chemotherapeutic laboratories, and the pesticide industry needs horticultural and agricultural experimental stations. Factories for synthetic fibers cannot do without a large technical department equipped to deal with problems of spinning, knitting, finishing, blending with natural fibers, and with the evaluation of wearing properties of fibers.

A modern large-scale chemical factory, therefore, operates a number of laboratories dealing with a variety of fields and supported by ancillary services such as library, patent department, literature department, physical laboratories, and technical

experimental groups. The cooperation of all these individual departments makes possible such results as the ammonia synthesis, coal hydrogenation, Buna rubber synthesis, and color film.

"Practical research," i.e., the creation of new products, the design of new processes, and the improvement of existing ones, as well as patent protection for these products and processes, are the essential tasks of the industrial laboratory. The realization that the chemical industry can stay competitive only by providing new products developed by research, was the impetus for the creation of a complex research organization. Thus, 20% of the products at present sold by Hoechst, originated in research work of the last five years; 20–30% owe their existence to work done since 1950, and 50% to work done prior to 1950. These figures show how handsomely research organizations repay the expenditure incurred on them. The proud achievements in the field of synthetic dyestuffs, nitrogenous fertilizers, plastics and synthetic fibers, of Buna, pharmaceuticals, pesticides, among others, provide further evidence of this.

We have in the Hoechst concern 1959 people with university training. In research are 675, all with a doctorate degree. We have some laboratories with five chemists and others with 80. I personally think that a laboratory with 12–15 chemists is of excellent size. One chemist has an average of one technician and one to two helpers. These nontechnical people are trained for their jobs by a company training school and by special courses. Young people coming from school sign a training-contract with the company. After three years of training and an examination by a committee, they are graduated as "Laborant." Technicians and engineers are similarly paid. Laboratory workers are generally paid a little less than those in production, but they have higher status. There is no difference in salary between production men and research chemists but the status of the latter is higher. The fact that the company is required by law to remunerate a research chemist who is the inventer of patents used, is a big stimulation to work in research. A chemist spends 75% of his time at the bench and if

he is a group leader only 25%; a laboratory head spends practically all the time in his office or at meetings. All chemists should start working for the company in a research laboratory before they go to production or administrative work. Only a few chemists are in sales. Customer service is done only by the chemists from the application department, sometimes in connection with salesmen. Research men are the company pool for promotions and for needs of the different departments. There is always a move in application or in production, but very seldom do chemists move to other companies. One reason is that a clause in their contract prevents work in a special field in which they worked before.

The chemists report frequently to their group and department leaders and each six months they have to write a report for the research director. Monthly reports are sometimes required. Once a year they have to report to the management. In the Scientific Directors meetings the reports are co-ordinated and the results are subsequently made known to management. After a chemist has finished a problem he writes a report covering the whole subject. Chemists are kept informed by means of a semiannual report of the president which deals with problems, progress, sales, social and other questions. The technical directors meeting is a means for exchange of information, which can be given to the public only in part. Normally a research man has no contact with customers for his working time is fully occupied on the company premises.

The personality of the head of laboratory has a great influence on the creative atmosphere and the morale of his research people. If his personality is suitable, he will have a successful laboratory benefitting all concerned. It is not satisfactory to hire some good research chemists, put them in a laboratory, and hope that some reasonable things result. More is necessary, as for example, a good alignment to the industrial aim, or the right recognition of a new trend which resulted by accident from a trivial observation.

The cost of this research work, which in the chemical industry amounts to 4–5% of sales, and in the pharmaceutical indus-

try to about 8% of sales, is a matter for the company concerned and is usually met from profits. These costs are, however, increasing. For instance, in the U.S.A., research expenditure of the chemical companies rose from 2.25% in 1955 to 4.25% in 1958, and in the pharmaceutical companies, from 4% in 1955 to 6.7% in 1958. For 1960, the increase is likely to be about 10%. Research costs of comparable companies in U.S.A. and in Europe are, therefore, of a similar order of magnitude. I estimate that the research expenditure of the German chemical industry is about 600 million DM per year.

Up to the First World War, because of the comparative prosperity of large sections of the population, the financing of the universities did not cause any great problems. After 1920, however, conditions changed and the Notgemeinschaft der Deutschen Wissenschaft, the Emergency Society for German Sciences, did much beneficial work. This society was intended to help not the Länder and their universities but the researchers and their work. Funds were contributed by the government as well as by trade associations and industry. The Rockefeller Foundation, too, made possible much basic research in the natural sciences, and also aided the arts.

The situation was much worse in 1945, at the end of the Second World War. Destroyed institutes, lost equipment and libraries, scattered staff and shortage of food and housing were the heritage of this terrible war. In addition, of course, under the Hitler regime many eminent Jewish scientists had been expelled from Germany. The amount of reconstruction done in the first postwar years and the scientific research work carried out under most difficult conditions deserve high praise, all the more so, as each research institute was left to its own resources.

It was not until early in 1949 that the Emergency Society for German Sciences was re-established in Cologne, and almost at the same time the Deutsche Forschungsrat, German Council for the Encouragement of Scientific and Industrial Research, was founded in Stuttgart. In August 1951, both organizations merged to form

the Deutsche Forschungsgemeinschaft, German Society for the Encouragement of Scientific Research, with four principal tasks: (*1*) financial support of research projects, (*2*) promotion of cooperation between research workers, and coordination of their work, (*3*) scientific advice to authorities, and (*4*) cultivation of relations between German and foreign scientists. Together with the Stifterverband für die Deutsche Wissenschaft, Founders' Association for German Science, an undertaking of German trade and industry, joined later on by the Fraunhofer-Gesellschaft zur Förderung der angewandten Wissenschaft, Fraunhofer Society for Promotion of Applied Science, these associations did much good work for the reconstruction of scientific research in Germany. The Founders' Association, for instance, provided 19.7 million DM in 1958; since its foundation in 1949, it has made available to German Science a total of 85.4 million DM. It is noteworthy that these associations are not greatly biased in favor of the natural sciences but are interested also in medicine and the arts.

Another source of aid is the Fonds der Chemie a foundation of the German chemical industry united in the Verband der Chemischen Industrie, Association of Chemical Industry. Already after the First World War the Justus v. Liebig Society for the promotion of chemical training, the Adolf v. Bayer Society for the promotion of chemical literature, and the Emil Fischer Society for the promotion of chemical research were established and financed by the chemical industry. It was therefore only natural that after the conflagration of the Second World War, the appeal to establish a fund for promoting chemistry, first made in 1946, met with favorable response. In 1950, the Fonds der Chemischen Industrie was established. Its tasks were: (*1*) research subsidies for institutes and individuals, (*2*) subsidies for chemical literature, (*3*) financial aids for inducing able young chemists to become university teachers, and (*4*) lump-sum payment of the contribution due from the chemical industry to the Founders' Association for German Science. At present the chemical industry spends DM 1 per employee per month. In 1958, the contribution

made to the Fonds der Chemie amounted to about 3 million DM which were used mainly for research subsidies; in 1959 it was practically the same sum. The total amount of money spent by the Fonds der Chemie within the last 10 years is 24 million DM.

In 1920, the first exhibition of chemical apparatus was held. Its great success convinced the organizers of the soundness of their idea, and led to the establishment of the Dechema, the German society for chemical apparatus, whose chief aim is the promotion of cooperation between chemist, engineer, and physicist in respect to apparatus, machinery, materials, aids, and appliances. It endeavors to attain its aims by giving lectures and practical courses, replying to inquiries, providing a literature service as well as by awarding scholarships and prizes. The European Federations for Chemical Engineering and Corrosion are developments that have translated into action the necessity for international cooperation in the scientific and technical field. The last exhibition of chemical apparatus, held in Frankfurt/Main in 1958 covered an area of almost 40,000 square meters and drew about 100,000 experts from 57 countries. The exhibition for 1961 is sold out.

The organizations which unite all those interested in chemical engineering and the construction of chemical apparatus, are important mediators between research and practice. The efficiency of scientific research depends not only on organization but also upon the never tiring spirit and obstinacy of the research chemist, who sometimes studies a problem for years, often at night and on Sundays. Successes are achieved only with difficulties. To a very great extent, it is a matter of the personality of the research worker. German research, particularly in the chemical field, has always been rich in such personalities. I would only mention such names as Liebig, A.W. von Hofmann, A.v. Bayer, Kekule, Ehrlich, Behring, Emil Fischer, Haber, Bosch, Willstätter, Bergius, Franz Fischer, Staudinger, but there are many others. Among the 42 German Nobel prize winners, 22 are chemists.

Even today, there are many people in Germany who are gifted and interested in research work and who have a feel for technical

processes. The qualities primarily required of a scientist are, accuracy, patience, and imagination, coupled with a balanced view of life free from egoism and envy. Above all, he must have a good team spirit, for most successes in research today are the result of good teamwork. Since the war, men of this kind have again made significant contributions to German research.

As in most countries, there is an association of chemists in Germany, the Gesellschaft Deutscher Chemiker, situated in Frankfurt/Main, whose object is the promotion of chemistry and the chemical profession by means of meetings and conventions of specialized groups (e.g., plastics and rubber, paints, hydrochemistry) by chemical training, scholarships, periodicals, subsidizing chemical literature, and by honoring eminent chemists with various awards. These include the Liebig, Adolf von Bayer, Emil Fischer, A.W. von Hofmann medals, the Carl Duisberg plaquette, the Alfred Stock memorial prize, the Gmelin-Beilstein medal, and the Otto Hahn prize for chemistry and physics.

In the Beilstein and Gmelin Institutes, which are housed together in the Carl-Bosch House, Frankfurt/Main, after the Hofmann House in Berlin as well as its library had been destroyed in the last war, German chemistry has two institutions that have spread its reputation far beyond the borders of Germany. Numerous scientific and technical periodicals, such as the Chemische Berichte, Liebigs Annalen der Chemie, Angewandte Chemie, Chemie Ingenieur Technik and a great number of specialized periodicals report on the research work done in the institutes and laboratories while enterprising publishers print the work of German and foreign authors.

German scientific research is therefore once again of a remarkable quality, and with increasing activity in years to come, will doubtless produce valuable results, thus also helping to solve social problems, for "research means work and bread."

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THE RESEARCH DIRECTOR AND HIS PEOPLE

P. J. KEATING, JR.*
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Introduction

Much has been written about scientists and their place in industrial research. It is an important subject and research directors must devote considerable time and thought to the problems, hopes, and aspirations of their people as well as to the mission of providing new products, processes, and technical knowledge.

It seems that emphasis has been placed on showing that scientists are "different" in some mysterious way and that they must be dealt with in a way not yet completely understood. It is just possible that the net result of this is that we may be making the subject more complex than it really is. Perhaps it would be wise to examine some of the simpler aspects of the relationships of people working with and for others.

If we remind ourselves that scientists are individuals who are similar in many respects to people with other interests and training, perhaps we can show that the problem is not overly complex

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and in fact can be a challenging application of considerate treatment of others.

On-the-Job Training

Training can take many varied forms, some of which are quite sophisticated. However, on-the-job training affords one of the most important and direct means for a supervisor to know and help his people. The research director creates the climate in which the supervisor can perform this training. The need for guidance can be readily recognized and the appropriate actions can be instituted in a friendly atmosphere. As a result, the scientist becomes an effective member of the team.

Choosing the Initial Assignment

The transition from academic to industrial life generally is not an easy one for the new graduate. Some take it in stride, but more often the research director must be alert to adjustment problems and the need and importance of encouragement.

During the initial interview at the laboratory it may be possible to establish the specific interest of a potential employee. Generally, however, it turns out that the research director is able to establish only an order of preference for areas of work. This is very useful and, when coupled with an accurate dossier giving the views and opinions of professors and previous employers, makes the selection of initial assignment relatively simple.

With adequate care the initial assignment will, of course, be challenging but not overwhelming and, above all, one fitted to the interests and talents of the scientist.

In a large organization, the new employee is apt to feel lost and to wonder if his research director really knows he is there. This attitude can be avoided, or at least minimized, by having the new employee visit the director after six and twelve months of service. If these visits are preceeded by appraisals from the man's immediate supervisor, the research director will be in a position

to comment on the employee's performance and discuss his assignment. It has been found advantageous to let the man do most of the talking. By asking a few questions concerning the man's satisfaction with his assignment and inquiring as to his need for help, the conversation in most cases moves easily and often ranges over a variety of subjects. It is important to have such contacts in a relaxed atmosphere. The director should devote his full attention to the interview and avoid outside interruptions.

In such discussions the research director has a wonderful opportunity to express his views and philosophy about his company that are important for the man to understand. The research director can also emphasize that much help is available for the asking and encourage the man to avail himself of the counsel of his group leader and supervisor. Above all, the scientist should be encouraged to communicate his ideas. Too frequently a new man may feel surrounded by experts and conclude that his ideas are not worthwhile or have been considered before.

Orientation

This is a process that can be quite sophisticated, at least at certain stages, and to a degree extends over one's entire career. If one looks back to his first day on the job one will probably remember some person who was considerate and offered some assistance—probably something simple but which left a lasting impression. At the start, the new man is in need of some very simple instructions and information so that he can begin to function. His associates should be reminded of this need. The research director can make the first day a pleasant experience by a welcome greeting in the morning and an invitation to lunch.

After a new scientist has had the opportunity to feel that he is an established member of the team, it is desirable and necessary to provide him with information concerning general company policies. More particularly he should receive information about his division or department; its responsibility, aims, functions, and

general operation. At this point it is not too early to emphasize that scientific and professional integrity are perfectly compatible with a responsibility to apply his contributions in a manner that will be most useful for his company's success.

Another way of helping the new employee is to provide an opportunity for him to visit other groups working in different fields. To be most effective this should be done after six months of service. If done earlier he will very probably not have the background to ask questions and obtain information that may be very helpful for his particular assignment.

Such a tour provides the opportunity to meet other scientists, to learn about their fields of work and to gain some idea of how the various activities are coordinated. These visits may last one-half to a whole day for any particular group. Thereafter, the man should be encouraged to seek help from other groups when he needs it and to have informal discussions with the professional people outside his group for stimulation and cross fertilization of ideas.

Sources of Information

The matter of communication and its improvement is, of course, an ever-present problem which becomes quite complex in a large organization. The new employee should be given help and guidance as to where to find information that will be of help in his particular assignment. One needs only to remember his own first assignment to appreciate the need for this kind of help.

At this early stage in a man's career some rather simple things can be extremely helpful. For example, selected correspondence can and should be noted to him. In addition, company reports bearing on past work that relate to his assignment will certainly give him a sound foundation and will eliminate the possibility of needless duplication of effort. It will also be beneficial from the standpoint of giving the man confidence to make suggestions, since he will have some knowledge of what has been thought of or tried before.

Proper use of the library is of value at all times. In the case of a new employee his supervisor should take positive steps to assure that the man is acquainted with the library, its efficient use, and the services it provides on a continuing basis. Also of importance is a knowledge of the specialized services that can be provided when needed.

Another device for the dissemination of technical information on work that is going on in a man's particular department or other departments is the practice of conducting informal seminars. The responsibility for arranging these can be assigned to technical people on a rotating basis. Programs can be arranged to provide subjects of general interest. Relatively early in a new man's career, he will be in a position to participate actively in such seminars in addition to obtaining new and useful information.

To supplement the informal seminars, a yearly lecture series for laboratory people can be stimulating and helpful. Again, the responsibility for making the arrangements can be placed on scientific people on a rotating basis. Lecturers should represent fields of general interest and should be men of outstanding accomplishment. When such people are invited to the laboratory, it is generally desirable to make arrangements for an informal discussion following the lecture so that those who have a deep interest in the lecturer's particular field will have the opportunity to hold discussion on a detailed basis.

Attendance at national society meetings and local section meetings, of course, is an accepted activity and should be encouraged. In the case of a new employee, the fact should not be overlooked that it will be desirable to allow him to attend such meetings early in his career because it provides the opportunity to renew acquaintances and share experiences with professors and friends who might have been in graduate school with him. This can be a bridge to ease the transition from academic to industrial life.

Another activity of considerable value is to arrange for courses of one to two weeks duration covering selected subjects. During this period the attendees should be relieved of their normal

assignment to devote full attention to the course. This becomes of more importance to a scientist the longer he is out of school because it provides the opportunity to keep abreast of developments in scientific fields of interest.

Established Scientists

As scientists become more experienced they naturally become more deeply involved in certain areas of work and become the experts in their field. They should have some opportunity of reporting and discussing their work with higher management. This, of course, has to be done with judgment for such opportunities can not be provided every time a segment of work is completed. Furthermore, it has to be understood that the supervisor is always responsible for the recommendations that may result from a man's work.

It often happens that a laboratory takes on a new area of work requiring scientific competence of a high order. The judicious use of qualified consultants can be both helpful and stimulating. Where this is done the supervisor should be careful to assure that the responsibility for conducting the work rests with the laboratory. The consultant must function as a professional advisor only.

The matter of job rotation is important and is likely to be overlooked or delayed unnecessarily. However, the fact can not be escaped that the need for changing a man's assignment can arise for a number of reasons. First and foremost is the fact that it provides the opportunity for broadening one's experience. It also arises as a result of company needs. A supervisor should be alert to the need for changing a scientist's assignment because he would like to try his abilities in other areas or because the supervisor recognizes specialized talents. These can only be recognized if the supervisor has a close relationship with his people and frequently avails himself of the opportunity to have informal discussions during which he can ascertain each man's hopes and aspirations. Then there is the case where a man is not

doing as well as would be expected in a particular assignment and it is imperative that his supervisor recognize this as early as possible and choose another assignment that will provide the opportunity best suited to his qualifications.

The opportunity to publish the results of one's work is generally accepted as desirable in industrial research. However, it is recognized that opinions on this vary in the extreme. A satisfactory climate for research should provide the opportunity for publication. The policy of the company should be thoroughly understood and the scientist should recognize that the work he has done is the property of the company and that the company must have the opportunity of capitalizing on it to the maximum extent before publication is permitted. Publications should represent a significant contribution to scientific knowledge and should be a credit to both the scientist and the company.

Recognition and Reward

It is very natural that all people, including scientists, want to receive recognition and reward for their contributions. Much has been written and said about this matter. Recognition of one's accomplishments can, of course, take many forms depending upon the nature and importance of the contribution. Without going into the many ramifications of this subject, it is suggested that the supervisor has many opportunities for commending a man and recognizing instances where he has done a good job or gone beyond what would be normally expected of him. If these instances are recognized at the appropriate time, they can have the desirable effect of letting the man know that his supervisor is aware of his contribution.

Generally, rewards take the form of salary increases or promotions and this is a subject that is being continuously explored. Suffice it to say that there should be a fixed policy, administered fairly and adequately to the best of a supervisor's ability. Unless a scientist has confidence in the policy of the company, he will not be satisfied.

The director should also recognize that a number of important awards are made annually for significant scientific achievement. He should be alert to these opportunities and the company should do everything possible to see that its people are considered for such awards.

Continued Coaching

Throughout a man's career it is almost universally true that he wants to know where he stands. This is a reasonable desire and the information should come from the man's supervisor. Some sort of evaluation procedure must be established so that the necessary information can be developed for use by the supervisor in his discussions with the man. This procedure should also provide information which will be helpful in suggesting to the man what he can do to progress toward the goals which he has set for himself. In other words, the supervisor should know the hopes and aspirations of his men and recognize that these probably will change with time. Armed with this type of information the supervisor will be in a position to offer encouragement to those who have the ability to attain their goals and to suitably advise those who may have set goals that are too high for attainment.

Summary

It is suggested that the relationship between a research director and his people has many facets. Some of these can be quite complex. However, others are relatively simple and can be handled by recognizing that a scientist is a human being with hopes and aspirations that differ only in degree from people in other professions. Many simple things can be done throughout a man's career to help him progress and be more productive. If these are done, the scientist will gain recognition, will have a sense of achievement, and will have the proper orientation toward his profession and his employer.

WHY PUBLISH SCIENTIFIC RESEARCH FROM INDUSTRY?

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I

The businessman and the scientist, though bound to one another by the technological base of modern industry, are uneasy companions. They have become symbiotic in the American economy but continue to view each other through a haze of misunderstanding. One symptom of this ailment is the disparate views they have toward the publication of scientific research from industry. Scientists demand freedom to publish new discoveries—and, it must be said, most often win their demand—while businessmen view this compulsion to publish as an invasion of proprietary business rights.

Although the argument is slowly being won by scientists who have persuaded enlightened managers that science itself springs from the shared knowledge of scientists, the issue still troubles the

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uneasy alliance of science and business. There are no objective measures to show the value of open communication of scientific research, and so the scientist cannot sustain his arguments with the objective demonstration he is accustomed to use in his work. However, many intelligent, perceptive people have considered the problems of science, technology, and the ill effects of secrecy on these enterprises.

This paper presents some of the recent testimony by eminent people to support the following theses.

(*1*) Basic scientific research is a primary source of innovations in industrial technology without this source of economic growth, our economy would stagnate.

(*2*) Restrictions on the traditional scientific practice of openly communicating the results of research are harmful to industry because they inhibit the generation of new science from which commercial opportunities arise.

(*3*) These general principles apply to individual companies that manufacture complex technical products because innovations in these businesses are following ever more closely on the heels of scientific discovery. To produce radical innovations, a technical company must produce good science.

(*4*) Any laboratory that must do good basic scientific research must also encourage open publication of research results because this policy insures access to the work of other laboratories. Open publication conforms with the traditional and indispensable working habits of scientists, and attracts the creative people needed by a good laboratory.

II

Modern technology—and, therefore, modern industry—have become deeply dependent on scientific research. The structure of modern industry would suffer if severed from the fruits of scientific research; economic growth would slacken and industrial activity would stagnate. Alert businessmen recognize this danger

and the management of many companies supports research, basic in conception and in pursuit, because it produces results that are needed by industry. Science is not the only source of innovation in a business; innovations in distributing and marketing goods, in sales and advertising, in the organization of human activities, may all contribute to industrial growth. But scientific research is one of the vital ingredients of this growth, and without it, technical progress would inevitably cease.

This relationship between science and technology is closer than it was in prior centuries, and the relationship is recognized more widely than ever before. ". . . We have learned that the apparently visionary research is likely to produce unexpectedly practical results. . . . Basic science, of course, is the essential underpinning of applied research and development" (D. D. Eisenhower[1]).

"The material well-being of a nation and its military strength rest largely and increasingly on the technical developments exploited by its industry. Basic research, the search for new fact and understanding, has provided and continues to extend and strengthen the foundations on which technical advance and new developments are built.

These statements are increasingly accepted as axioms of our society. It is hard to find examples of industrial products or services that do not owe some debt, in many instances their very existence, to basic research" (J. B. Fisk[2]).

"I have just mentioned a distinction between the industrial revolution and the scientific revolution. . . . By the industrial revolution I mean the gradual use of machines, the employment of men and women in factories, the change in this country from a population mainly of agriculture laborers to a population mainly engaged in making things in factories and distributing them when they were made. . . Out of (the industrial revolution) grew another change, closely related to the first, but far more deeply scientific, far quicker, and far more prodigious in its results. This change comes from the application of real science to industry, no

longer hit and miss, no longer the ideas of odd 'inventors,' but the real stuff" (C. P. Snow[3]).

"Again, modern physics began about 1900, with all its immense implications for technology and for the relation of science to industry. Now for the first time, abstract scientific thought, carried on without concern for its practical consequences in the life of man, was to offer as an incidental reward a mastery of natural resources totally different in kind and scale from anything contemplated in the older technology grown from remote empirical roots" (C. Singer et al.[4]).

"A rather good parallel to our present situation existed at the time the potato was introduced and eventually became the major foodstuff in Ireland. Here was a plant which could convert solar energy into food with far greater efficiency than any plant which had existed previously in Ireland. As a result, the death rate dropped, and the population increased with dramatic suddenness.

The society functioned smoothly as long as the potato thrived. But one fateful year, potato blight appeared. . . . The community, which had become almost completely dependent on the potato, was decimated, and today—more than one hundred years after the great famine—Ireland has yet to recover completely.

In a very real sense our science and technology is to us what the potato became to the Irish. Just as Ireland collapsed when the potato crop failed, so modern civilization would collapse if our technology is unduly disrupted or if our technological knowledge fails to keep pace with the needs and demands of the atomic era" (H. Brown[5]).

III

The businessman, striving to cope with rapid technological innovations in a competitive business, will often question the importance of publishing a new and, perhaps, economically valuable scientific discovery when such publication will inform his business competitors of the development. He may regard publishing as an

ego-satisfying game played by scientists but not as a vital part of scientific work. The opportunity to publish is, indeed, a psychological reward for scientists but publications serve needs more critical than just that.

The scientific paper which reports new discoveries, theories, or observations originated in the seventeenth century shortly after the birth of Western science. This means of communication between scientists grew out of the practices of writing letters and of reading formal discourses to scientific groups. Published papers supplemented these earlier modes of communication; they satisfied the real need for short written reports that could be circulated among a dispersed audience. This type of communication has changed but little during three centuries, and the growth in number of papers published has paralleled the growth of science so closely that a simple count of the number of published papers has become a good measure of scientific activity. This close relationship indicates the dependence of scientific progress on rapid, widespread dissemination of new results.

"Destroy the social nature of scientific research in the sense of destroying the intercommunication of scientists, and the advance of science would almost cease" (J. B. Conant[6]).

"Secrecy and science are fundamentally antithetic propositions" (J. B. Conant[7]).

"Rapid exchanges of information have been vital to this progress. What is done in one laboratory today may depend on results obtained in another laboratory in a different part of the world only months before. For example, one of the most exciting developments of the past three years was made by a physicist working in an industrial laboratory in Japan. His idea was soon taken up and is now being pursued by several laboratories in this country.

With its very advanced technology, the United States is able to take best advantage of any new development in the field. The most important thing is to spare no effort so that our country remains in front and does not lag behind. We then have nothing

to fear and everything to gain from free exchanges of scientific information" (J. Bardeen[8]).

"Unfortunately, secrecy and progress are mutually incompatible. This is always true of science, whether for military purposes or otherwise. Science flourishes and scientists make progress in an atmosphere of free inquiry and free interchange of ideas, with the continued mutual stimulation of active minds working in the same or related fields. Any imposition of secrecy in science is like application of a brake to progress" (K. T. Compton[9]).

IV

The preceding general principles apply also to individual companies that manufacture complex technical products; they cannot be only a parasite on the total body of scientific knowledge and expect to prosper. The new applications of science are being extracted from the stream of science nearer and nearer to the springs of discovery, and companies are increasingly recognizing this development by extending their research and development work toward more basic problems.

An early leader of industrial research was Willis R. Whitney, first Director of the General Electric Research Laboratory, and he was a strong advocate of the ultimate value of basic research to individual companies.

"I have such great respect for the value of pure research that I am inclined to the belief that good men put on research in any field could not fail to show returns in time" (W. R. Whitney[10]).

". . . in today's world the inventor and the scientist, though sometimes the same man, are more often distinct; yet they are far more dependent one on the other than in the past . . . . increasingly the practical developments of our time rest on things which were not known to our fathers, and often on things which were not known to us when we went to school" (J. R. Oppenheimer[11]).

"In the heyday of the inventor, which I regard as being the nineteenth century, the elements of science at his disposal were

relatively rudimentary and he was able, operating with those and with the aid of very little mathematics or elaborate theory, to apply the new knowledge by a series of largely empirical procedures" (J. B. Conant[12]).

By 1940 the scene had completely altered: Science had moved into industry and, belatedly, even in the United States, industry had moved into science. The electrical, the chemical, and the pharmaceutical industries may be said to have led the way. The great research laboratories of the General Electric Company, the Bell Telephone Laboratory, and the duPont Company may be mentioned as examples" (J. B. Conant[13]).

"I can state the interest of General Electric in basic research by saying that we are engaged in this creative activity because we regard it as a primary source of new knowledge and understanding which, translated to new or improved technologies, presents important opportunities for new business enterprise" (C. G. Suits[14]).

". . . No one who comes in close contact with modern science, even as a watcher, can fail to appreciate its effect on all aspects of human life. Since World War II, science has overshadowed industry. No large manufacturing concern can compete effectively without aggressive research . . ." (J. N. Leonard[15]).

V

Businessmen would never disagree with scientists about whether to publish scientific papers if the results of research were unimportant to commercial interests. Precisely because the fruits of basic research are important to industry, the pressures to prevent or abridge open scientific publication exist.

Even though testimony about the importance of publications to the total body of scientific knowledge has been given in Section III, there might still be a question of whether any importance really attaches to the scientific publications of a particular industrial laboratory. Could not each industrial laboratory remain

silent with its discoveries and let the published literature be filled only with the work of universities?

The answer to this question clearly is *no*. Industrial laboratories now produce a substantial fraction of the fundamental scientific discoveries (in 1957–58, about one-third of the $835 million spent on basic research in the U.S. was spent by industrial laboratories[16]) and the growth of science, particularly in the U.S., would be jeopardized by this restrictive policy. But, the answer is still *no* from the selfish point of view of an individual laboratory. The reasons why an industrial research laboratory must have a liberal publication policy are:

(1) By producing and publishing good science, industrial scientists are able to have access to the laboratories and knowledge of the whole world of science. A laboratory that does not allow its scientists to publish will quickly find itself alienated from the world of science, for productive, creative scientists do not welcome the intrusion of other scientists who wish only to prey on their discoveries.

(2) Creative scientists, in order to do their work well, depend on having this work appraised and recognized widely in the world of science. This is a long, established tradition in science and persons doing fundamental research will not do it well in surroundings that too severely abridge open communications.

(3) Good science is produced by good scientists. But to recruit and hold good scientists, an industrial research laboratory must encourage open publication of research results.

Most creative scientists share the view of one of the fictional scientists in *The New Men*, a novel by C. P. Snow:[17]

". . . keeping scientific secrets . . . was to him a piece of evil, even if a necessary evil. In war you had to do it, but you could not pretend to like it. Science was done in the open, that was a reason why it had conquered; if it dwindled away into little secret groups hoarding their results away from each other, it would become no better than a set of recipes, and within a generation would have lost all its ideals and half its efficacy."

"The industrial research laboratory, moreover, must not operate in a vacuum, in theoretical self-sufficiency. An important part of its function is to interpret appropriate world science to its parent organization. It would be unrealistic to suppose that all of the scientific information that any industrial organization might use could be produced in its own laboratory. It is now generally appreciated that in order to partake of world science, the research laboratory of industry must also participate in and contribute to world science. For this reason, the laboratory must publish its findings promptly, and its scientists must be encouraged to take active part in the meetings of their colleagues throughout the world" (C. G. Suits[18]).

"Freedom of publication and encouragement of sound and timely publication, these, too, are important to the research environment and can be achieved in industry. Most scientists today understand the need for prompt patent applications, and a well-organized laboratory can get such work done expeditiously. Hence, patent questions need cause little delay in publication. But in any event, secrecy is unattractive in basic research—and is very seldom necessary. The communication of knowledge is a responsibility of scientists, a most important mechanism of scientific advance. Any research institution which draws value from the work of others through their publications has in some degree an obligation to return value in kind. The extent to which a laboratory does so will weigh heavily in the appraisal which scientists make of it as a place to work" (J. B. Fisk[19]).

" 'Property' rights in science are whittled down to a bare minimum by the rationale of the scientific ethic. The scientists claim to 'his' intellectual 'property' is limited to that of recognition and esteem . . . .

The institutional conception of science as part of the public domain is linked with the imperative for communication of findings. Secrecy is the antithesis of this norm; full and open communication its enactment . . . . A scientist who does not communi-

cate his important discoveries to the scientific laboratory becomes the target for ambivalent responses" (R. K. Merton[20]).

VI

The preceding testimony argues that commercial interests will suffer rather than benefit from restrictive publication practices. But how are the commercial values of scientific research to be extracted if new discoveries and understanding are openly published? First, the commercial values can be extracted by obtaining and using patents. Second, vigorous development and engineering programs must closely follow new scientific developments. This rapid translation of scientific discovery into useful products is becoming a critical function of industrial research; the applied work and the scientific work are intimately dependent on one another in order for either one to be profitable for an industry.

Finally, and related to this last point, the company that is technologically most capable and alert will benefit most from open communications, for it will be able to exploit rapidly the opportunities presented by the science of the open literature.

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PROCEEDINGS OF INDUSTRIAL RESEARCH INSTITUTE STUDY GROUP MEETINGS.

NUMBER 3. SELECTION AND PLACEMENT OF RESEARCH PERSONNEL*

STAFF REPORT

Introduction

The Selection and Placement of Research Personnel was one of three topics in the IRI series of study group conferences for 1960. Two sessions were devoted to the subject, one in New York City on February 16–17, the other in Chicago on March 15–16. On both occasions, the discussions were led by James A. Bralley, Director of Chemical Research, A. E. Staley Manufacturing Company, and D. Lorin Schoene, Assistant Director of Research and Development, U. S. Rubber Company. The participants numbered 16 at the first conference and 15 at the other. Not more than one representative per company was present at a session and a good cross section was obtained of the extensive segment of American industry that is deeply committed to research.

The men who attended were well selected. They had valuable experience in the problems involved, and they came to learn by presenting their views and sharing experiences. The small size

* The circumstances which led to the formation of Research Management Study Group Conferences, and their objectives are covered by Vaughn in *Research Management*, 3, 93 (1960).

of the group encouraged a relaxed, informal, roundtable type of discussion which prevailed through both days of each session.

The proper selection and placement of research personnel constitute functions which are as vital to a company as research itself. An organization that is successful in attracting technical men of high quality and in making optimum use of their competence is the one that maintains its competitive position and ensures its economic growth and prosperous future. A full discussion of the topic required consideration of several aspects including recruitment, evaluation, placement, orientation, appraisal of performance, personal guidance, communication, and others.

Recruitment and Preliminary Evaluation

All of the companies represented rely heavily on recent graduates with the Ph.D. or lesser degree. Their caliber is assessed by study of scholastic records, recommendations, impressions at personal interviews, and other aids which can be brought to bear on the evaluation process. Discussion of these techniques was spirited and revealing of varied outlooks and interpretations.

For example, there was a consensus that the most competent men are likely to be found among those with the best scholastic records. How much reliance can be placed on such records? One of the participants, a representative of a highly regarded research organization, called attention to schools which specialize in coaching students to do well in examinations. Their graduates may be quite successful in this aspect but do not by any means make the most competent workers. Going further than that, he stated the conviction that many individuals of superior creativity are denied admittance to colleges because they lack the ability to demonstrate their qualities in examinations. They are thus severely penalized to the detriment of themselves and the companies that are deprived of their services. While scholastic records may be a useful tool in screening out the unfit, one must be alert to the danger that those with superior native endowments may also be eliminated in the

process. The latter type is much sought after at any time, and particularly in these days of shortage of scientific personnel, a company does well to devote unusual effort and ingenuity to the procurement of individuals of superior potential.

Extracurricular activities provide a fairly reliable indication of a student's interests and attitudes. These may be discerned in the nature of the societies he joined, his activities in these societies, and in the other functions, including athletics, in which he engaged. One participant referred to a study which demonstrated that men who engaged in extracurricular activities achieved greater success in their careers than those who limited their efforts to the formal curriculum.

Many companies have recruiters who specialize in the preliminary selection of candidates from universities. These men generally have well-established contacts at certain schools where the professors are familiar with company requirements. Experienced recruiters do a good job of first-stage evaluation. They are in a position to examine not only the scholastic record of a man, but also to make first-hand inquiries from which to estimate the many other criteria—character, integrity, originality, initiative, attitude toward science, cooperativeness—which in the long run prove so important in determining success. Recruiters are usually scientific people who speak the language of the young scientists, and they are able to perform the dual function of describing the company to the man and making a fair estimate of his potential worth to the company. The candidates they invite for further interviews on the company premises generally prove to be those whom the organization does want to employ.

In cases where a recruiter is not available to obtain information at first hand, experience has demonstrated that estimates of a man's qualifications are best obtained by telephone rather than by letter. The person contacted is more likely to be candid when he gives his appraisal orally particularly if negative qualities are involved. Telephone communication has the added advantage of saving time for all concerned.

Campus recruitment has assumed such proportions of late years as to present a real problem to some institutions. A great deal of time of university people is taken in consultations with recruiters, preparation of personal appraisals, and answers to routine inquiries. Institutions of learning have, in addition, their own problems in procurement of suitable men for the teaching staff. Companies are giving thought to this matter with a view to minimizing the burdens placed on the universities by the industrial recruitment function.

As a gesture of appreciation for the efforts of university people, a company may invite certain of the professors to visit its plants and laboratories to learn the nature of the operations which they can then relate to the type of recruit best suited to meet the requirements. Several participants noted too that a professor will occasionally refer suitable candidates to the organization that utilizes his services on a consulting basis.

The evaluation of recommendations and scholastic records must be based to a substantial degree on knowledge of the persons who made the appraisals, and of the institutions in which the grades were obtained. The estimate of one professor can be much more accurate and meaningful than that of another, and the same grades have varying significance in different schools.

Final Evaluation of Candidate

When a candidate is invited and agrees to visit a company, the opportunity is presented for detailed discussion and observation. The occasion is an important one for it provides information, in addition to that already obtained, upon which the decision regarding an offer of employment is based.

Some companies give advance notice to the invited candidate that he will be expected to make a presentation and answer questions on the subject of his thesis before a selected group of his peers. Careful advance study of the thesis is made in order to determine the questions to ask. The candidate's presentation and replies to

the questions can be quite revealing of his intelligence, originality, comprehension, reaction to criticism, and even creativity. Results of the discussion are evaluated to determine his qualities; to learn whether he followed the directions of his professor and if so, did he do this more or less blindly, or did he try to find the reasons for each step—or did he himself devise the approaches which were employed. The personnel designated by a company for these little seminars should be carefully selected to assure objective, unbiased appraisal.

In connection with the matter of thesis work, an incident was related of a young researcher whose qualifications were generally regarded as superior. He accepted invitations of several companies for interviews all of which were followed by offers of employment. His choice was based on this reasoning: All of the companies had certain of their personnel meet with him to discuss his thesis, but only one had scientists who critically reviewed the paper and asked him questions about it which he could not answer. The young man decided that the scientific climate provided by that company was the one in which he could best develop.

Several participants reported that their interviewers are not only selected with care, but also given special courses of training. At least one of the companies established the policy that no other duty of an interviewer has priority over that function.

In determination of the candidate's suitability one participant offered these criteria:

(*1*) Formal education and training;

(*2*) Accomplishments in previous assignments in the academic and industrial fields;

(*3*) Creativity;

(*4*) Originality and self-direction. Does he have ideas of his own and can he develop them, or does he work best under direction of others?

(*5*) Knowledge of current scientific progress particularly in the field of his specialty;

(*6*) Ability at self-expression, written and oral;

(*7*) Potential in research, administration, or management—a most difficult quality to evaluate, but an estimation can be made;

(*8*) Personal attributes—a broad category which includes character, intelligence, motivation, cooperativeness, and appearance;

(*9*) Personal and family satisfaction with the location of work. This aspect is not without its importance, for many a man has found it expedient to change his job because his wife was not happy in the town where the laboratory was located, or for other personal reasons.

An examination of these criteria reveals the complexity in this matter of evaluation covering as it does an extended breadth and depth of personal qualities, and other factors. Those which pertain to education, accomplishments, creativity, and knowledge of current trends can best be estimated by the candidate's scientific peers. Other attributes may be left to the judgment of the personnel department. However, any special assistance which will enhance the correctness of overall evaluation is more than welcome, and many companies claim that such aid can be provided by psychological techniques.

Several organizations reported use of the Wonderlic test for estimations of intelligence. One participant was pleased with the results of a test—of five minutes duration—said to provide an indication of creativity. That quality is indicated, according to the experience of two companies, by the applicant's answers to a series of questions dealing solely with biographical and sociological data pertaining to him. Several of the companies use extensive psychological testing by an outside agency at a cost of about $150 per man.

It was emphasized that the psychologist's report of test results constitutes a staff document. The decision on employment is in all cases a line decision. Several companies reported instances where a man was hired despite the indications of the tests, and vice versa. One participant stated that people considered for appointment to senior grade positions in his company were inter-

viewed by psychological consultants whose reports in most cases were in accord with conclusions reached by other interviewers. There were a few instances in which men were hired despite psychological reports indicating unsuitability, and in those cases the subsequent experience of the company revealed that the services of the men were marginal or unsatisfactory.

Aside from the results provided by the tests, the reactions of a candidate who is asked to take them are worthy of note. Two persons were of the opinion that a man who, for example, resents taking the tests may have a personality unsuited to day-to-day contact with fellow workers.

Handwriting analysis has been used for many years in European countries as a means of personnel evaluation. The technique has very limited practice in this country possibly because of a shortage of experts and limited recognition of the art itself. The system does, however, have its proponents who claim that it can disclose important characteristics in an economical and effective manner.

The "Odd Ball"

Technical people acknowledge that the field of science is well sprinkled with instances of highly creative achievements by men who deviated substantially from the standards of behavior which the custom of the times had decreed as normal. Participants at one of the sessions engaged in an interesting discussion of the scientists who, for want of a better name, are here termed "odd balls."

Quite a few organizations stated that they would be very glad to acquire the services of such men, but at this point the old matter of recognition arose. One participant phrased the problem in clear if blunt language when he asked "Is the man screwy and good, or is he just screwy?" That indeed is the problem, which demands correct solution for woe betide the organization that hires a few screwy individuals in the mistaken belief that they are screwy and good.

One company related that it had made a conscious effort and

recruited two "odd balls." The results were disappointing—to say the least. Another person asserted that the significant technical achievements in his organization were made by quite normal people well suited for promotion to positions of management.

The creative "odd ball" does exist. Correctly identified and properly assigned, he is a decided asset to an organization in which the management and other personnel present no impediment to his development.

Some Means of Attracting Applicants

Scientific Reputation

The discussions at both sessions emphasized that young men, particularly those with graduate training, are science oriented. They are attracted to organizations that have won recognition for technical achievements. Especially is this true of accomplishments in fundamental research.

When the young scientist reports for an interview, it is well to recall that the academic world of college and university has been his environment for years. Companies skilled in the art of recruitment provide sympathetic interviewers who appreciate the viewpoint of the new graduate. They know that nearly every scientist who casts his lot with industry, starts his career as a science-oriented individualist who eventually becomes distinctly product oriented. They realize too, that an easing of the transition from one to the other, can have a beneficial effect on a man's morale and development, and works also to the best interest of the company.

The organization that has a segment of its research department devoted to fundamental work will generally have papers in journals of pure science. One or more of its outstanding men may be invited to present talks at university seminars. The very presence of such men in an organization facilitates recruitment of competent young people who want to work under their tutelage.

Summer Employment

A device which, properly applied, has been beneficial both to the young scientist and the company is the summer employment of students who plan to specialize in fields of interest to the company. Many of the better students are eager for the kind of summer work in which they can utilize knowledge already gained, learn more about the industrial approach to research and development, and above all, achieve research objectives (necessarily of short-range nature). Some companies devote substantial effort to devising summer programs which present a realistic challenge to the beginning scientist. After his return to school, he is kept informed of developments in the project on which he worked. When warranted, his name appears on a paper or patent. All of this effort has been found to pay off in the development of a sense of loyalty to the company, and a determination to work there on the completion of studies. One very large and diversified company reported that a gratifying proportion of the summer workers subsequently applied for permanent employment, and the indications were that their termination rate was lower than average.

Several participants cautioned that a summer program can operate to the detriment of a company. Students want to do challenging work, and if they are assigned to ill-conceived, makeshift tasks of little or no consequence, they will resent it. They will develop an adverse opinion of the company and generally can be depended upon to communicate that opinion to fellow students.

Company-Supported Education Program

A practice which has been widely adopted of late years is the underwriting of expenses for continued study. The typical company pays the full tuition of a man studying on his own time in a field of interest. Where the employee has to take courses during business hours, a substantial portion of the tuition charges are borne by the organization. The arrangement has mutual advantages. A suitable course of study leads to a higher level of

technical achievement in the research work of the organization, and a scientist can have the satisfaction of a graduate degree made possible by the financial assistance and encouragement of his employer.

Research laboratories located at a distance from a center of learning and even those in a metropolitan area may arrange for specialized courses on company premises. The subjects may involve, for example, higher mathematics, reaction kinetics, instrumental analysis. Each course is generally given by recognized outside experts, for a period of two weeks, full time, and attendance is on a voluntary basis.

Recruitment and Unions

The experience of one company indicated that the existence of a professional union in a research and development organization is a serious handicap in recruitment of the more competent men, particularly at the Ph.D. level.

Orientation and Placement

When the qualifications of a man are considered satisfactory and he accepts the offer of employment, he reports to the company ready and eager for his first assignment. Some companies devote less effort to the efficient processing of a new employee than they do to enticing him into the organization. On occasions the scientist is left cooling his heels in various offices. He gains the impression that the organization does not know what to do with him because of the inordinate length of time wasted before he is finally escorted to the laboratory where he is to work. The delay has a bad effect on morale. Better coordination among the departments concerned would undoubtedly expedite the processing function.

Men who have the doctorate degree are generally hired for work in a specific field which was discussed and selected during the interviews. In most cases, these scientists do not go through a

period of orientation. The young researcher may work for a year or more in a field—quite often exploratory research—in which he believes that he is best qualified. Part of the time, he may be under the tutelage of an older man. Many companies favor this arrangement particularly when it is understood to be an informal and temporary relationship. The senior scientist should be a man who has both aptitude and desire for the training of younger colleagues. This first supervisor should be one who can encourage the breadth of vision and intellectual curiosity fostered in a university. After a year or two, the young worker has learned a good deal about the company and its operations. He is now in a mature position to decide the line of work he prefers, which may be quite different from that which attracted him at the start. Most companies make a practice of accommodating the desires of the young man wherever possible.

One participant, however, related an incident where the desires of recruits were set aside to meet the demands of a "crash" program. All of the men did very well, and most wanted to stay with the project into the development stage. The fact that the objectives were accomplished successfully by new men was attributed not only to their technical competence but equally to the strong sense of motivation provided by the importance and urgency of the program.

Most participants were of the opinion that the first assignment of a recruit should be one in which he has a favorable chance of achieving positive results. Success has a fine effect on morale and makes for a feeling of identity between the man and his organization. Subsequent problems may of necessity be more difficult, and will be followed in many cases by disappointments which the man will have learned to take in his stride.

New employees with the B.S. or M.S. degree are given rotating assignments in some companies. That procedure assures an effective course of training and orientation and provides mutual opportunity for determination of where the employee best fits into the organization. One of the participants described the system of

rotation which has been utilized by his company for more than a decade. The course of training requires about one year during which the employee has tours of duty in each of several research sections. The duration of each assignment may be several months, but it is quite flexible. While assigned to a section, he is paid from its funds, which generally implies that his work is devoted to problems of current interest. Each assignment is followed by a performance appraisal. During the entire period, the man is under the administrative direction of a department devoted to education. At the end of the training period, the performance appraisals are evaluated, consideration is given to the suitability of the man, to the matter of a merit increase, and appropriate discussions lead to a decision on permanent assignment.

Some companies provide a course, generally of an informal nature, designed to acquaint the newcomer with company operations and aims. The orientation consists of talks by representatives of research, development, manufacturing, sales, market development, budget control, and possibly other functions. One or two hours per week extended over several weeks are set aside, and the course may be held once a year or at such other interval as indicated by the number of recruits. Many organizations have the standard practice of inculcating their rules for safety immediately after a recruit reports for duty.

Performance Appraisals and Personal Guidance

In these days when so much effort is devoted to control, evaluation, measurement of performance, personnel development, getting the most out of the research dollar, one of the participants representing a large and highly regarded organization startled his colleagues with the statement that his research and development laboratories had never adopted a formal appraisal system. This gentleman asked the opinions of the others regarding the desirability of instituting one and the consensus was that a formal ap-

praisal system while taking a good deal of time and the cause of much grumbling is, nevertheless, useful, provided it is kept simple.

The design of an appraisal system should be no more elaborate than the information it is intended to provide. If the management wants to know whether the services of a man are excellent, good, or unsatisfactory, the appraisal form can be simple, and can be completed by the supervisor in minimum time provided, however, that he has, in fact, consciously sought data upon which to base his estimate for the period covered by the report.

Many companies want to carry the appraisal technique further in an attempt to determine those aspects of a man's work susceptible of improvement. Still more detailed is the effort to identify the limitations in his education and training which bar a higher absolute quality of performance. There is also the important element of estimating the optimum potential of a bench worker, whether it be in science, administration, or management. All of these elements can be accomplished but require an elaborate system of appraisal, a great deal of time of supervisory personnel, and a high degree of skill in collecting reliable data and determining their significance. There was no disagreement with the conclusion that a company desirous of instituting formal appraisals does well to adopt, at the start, a system of maximum simplicity. The system should provide data for recommendations which will help the man become more valuable to the company and himself.

When a supervisor completes his formal appraisal, the accepted practice is to discuss the report with the worker concerned. Where there is mutual confidence and respect, the points of weakness as well as the favorable factors are acknowledged. In that connection, it was noted that the practice in one company is for the bench worker to complete his own personal appraisal form independently of the supervisor. In most cases, the content of both forms is in substantial agreement. Under such conditions, the discussions between the two men can lead to good understanding of means for improvement. Instances of disagreement and misunderstanding do, however, occur, and in the interest of fairness, a system should

make provision for the filing of an exception by an employee who thinks he has been rated unjustly. One company has adopted the practice wherein the appraisal of an individual is accomplished by a group consisting of the supervisor, possibly the section chief, and one or two others who know his work. Their effort, according to the experience of this organization, results in accurate appraisals which are effective for management purposes, and helpful to the individual concerned.

Management has, on occasion, learned to its surprise that a research worker does not have a clear understanding of his duties. The appraisal and subsequent discussions provide the opportunity to remove the difficulties. Most persons were of the opinion that performance appraisals should not be tied, in point of time, to considerations for merit increases.

Inseparable from the concept that the performance appraisal is a management tool for control, is the fact that it does also point the way to personal improvement and development. Particularly is this true when the appraisal is supplemented by an informal system of personal guidance for the latter can never be replaced.

The good supervisor has skill in human relations. He knows that the transition from academic to industrial life is a difficult period in a man's career. Proper counselling, which in some cases may involve nothing more than a few kindly words of encouragement, an attitude of interest and understanding can have a most beneficial effect in his adjustment. The source of a man's difficulty is quite often elusive, particularly when he is somewhat inarticulate and sensitive, but here too the experienced supervisor develops the ability to discern just what it is that is causing trouble. Once the difficulty is known, appropriate action can be taken to the benefit of all concerned.

RESEARCH MANAGEMENT AT TEXAS INSTRUMENTS*

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Texas Instruments Inc. Dallas, Texas

General Considerations

The two major elements in the management of research are planning and directing. While planning involves mental formulation and sometimes graphic representation, it is unfortunate that the latter is too frequently emphasized. The result is often a mere exercise in numbers, which has given planning an undeserved bad name synonymous with futility.

An adequate plan must have an objective, a procedure, and an assignment of responsibilities. Authority commensurate with responsibility must, of course, also be assigned. In my opinion, authority can very nearly be measured in the dollars that a project manager is authorized to commit without consulting higher authority.

* Presented at the Spring 1960 meeting of the Industrial Research Institute, Virginia Beach, Va., May 8–11, 1960.

† R. W. Olson obtained his bachelor's degree in electrical engineering from the University of Minnesota in 1938. He was a radio engineer with the Magnolia Petroleum Company and during the war years he was an engineer with the Department of the Navy. Subsequently, he became chief engineer for Geophysical Service, Inc. From 1953 to 1957 he was president of Houston Technical Laboratories, a subsidiary of Texas Instruments Incorporated. In 1957, he was appointed to his present position, Vice President, Research and Engineering of the parent company.

Management accomplishes the direction of research through the organizational structure with particular reference to the immediate supervision. The planning of research requires that objectives be set and operations are performed in order to achieve the objectives and fulfill the responsibilities with regard to costs which should have a reasonable relationship to the planned costs.

Sometimes the objectives are broad: the company will engage a man of unusual talent in a particular disciplinary area and "turn him loose." At other times, the objectives are specified within narrow limits.

The performance of research cannot be covered by a work order which is detailed in operational steps and simultaneously valid. It is my experience and belief that the procedures for achieving objectives are practically limited to the selection of individuals with particular skills and allowing them to function. Particularly in creative work is it difficult for management to outline a procedure unilaterally. Only the man who performs the creative work can set forth a detailed procedure which he does frequently piece by piece as he proceeds. This however, is one key to the consideration of my discussion. Planning must be the result of the joint efforts of the management of the company, the management of research, and the project manager who will direct the performance of the work. The responsibilities for achievement can in all cases be set as precisely as the objectives.

Research Plans

The earliest "plan" still extant for research, development and engineering activities at Texas Instruments carries a 1948 date. This plan is remarkable in a number of ways. First of all it was much too detailed. Secondly, in some areas it was followed fairly well. Thirdly, and, fortunately, for the growth of the company, it was utterly superseded in some areas. Finally, we devoted major efforts to areas not even alluded to in the plan.

The 1948 plan covered very limited activities involving as it

did less than $200,000, but it was a beginning. Later, we proceeded into more serious planning. In 1952, for example, the entire top management of the company, including the Chairman of the Board, met for a week to solidify our thoughts. The preliminary plan for Research, Development and Engineering presented at the meeting ran to 200 type-written pages, as well as many tables and graphs. It covered the work of about a hundred scientists and engineers in great detail right down to estimates of costs of every subproject in the whole organization. It developed into a fairly good plan, and we followed it fairly well. We accomplished the desired results, but the graphic representation required too much effort for the guidance derived.

In the twelve years that we have retained our recorded research plans, we have gone through at least twelve different methods of planning, each increasing in detail and complexity up to 1954 when the company became decentralized or divisionalized. The *total* resulting plan was then even more complex, but for any one division it became relatively simple.

The increase in detail and complexity continued apace until June 1959 when our current long-range research plan was made. It was a staggering piece of *paper* work which caused many of us to resolve "never again." The plan is being fairly well followed and excellent results are being achieved, but the cost in effort was prohibitive.

The Technical Organization at Texas Instruments

Our organization is planned and built on the dual concept of product supplied and customer served. The term we use is product–customer centering which means a great deal to us philosophically and in practice. That concept is, in fact, the guiding philosophy in our organizational structure.

To illustrate, let us examine Figure 1 which is a skeletonized chart showing the organization of the division for which Texas Instruments is probably best known, the Semiconductor Compo-

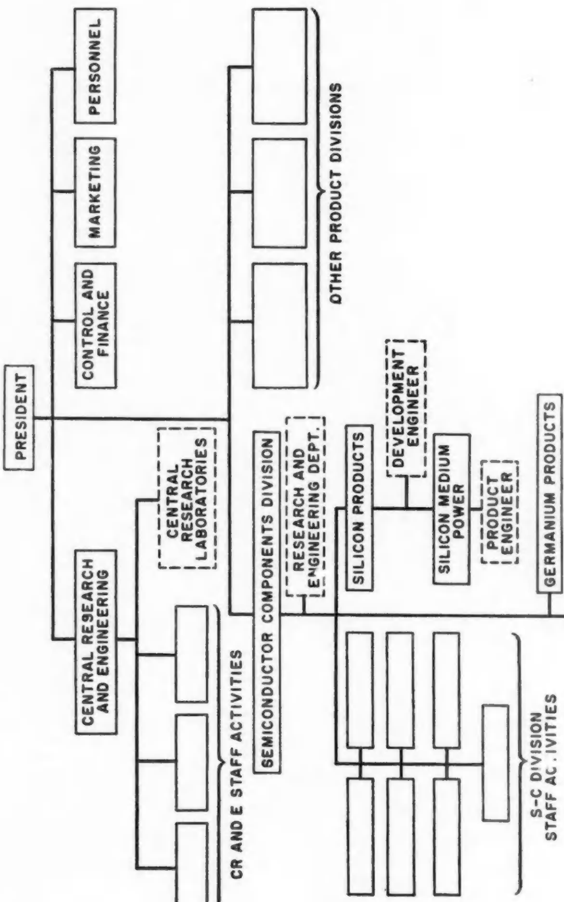

Fig. 1. Skeletonized organization chart illustrating four levels of technical effort. (Dashed boxes are areas of technical effort.)

nents Division. It consists of a research and engineering department and three product groups: silicon products, germanium products, and components. Each of the product groups has product-line departments.

The research and engineering department specializes in solid state physics, semiconductors, and similar fields. Each of the product groups has a development laboratory that develops new products for the product-line departments within the group. In addition, each of those departments has its own engineers whose outlook is relatively restricted. They do engineering—plain, pure, but rarely simple. They keep their eyes (and thoughts) right on the particular "product-ball" engaging their attention. They do develop new products in their areas from time to time, but current demands detract from this function.

Within the Semiconductor Components Division we have three levels of technical effort: (*1*) product-line engineering; (*2*) development of new products within a product group, and (*3*) applied research and engineering in a relatively broad area in support of the present and future products of the entire division.

At this point, it would be well to introduce the definitions of research, development, and engineering in effect in our organization:

Research

Research is that activity aimed at increasing scientific knowledge and understanding. It includes both basic and applied research.

(*a*) Basic research is that in which the primary aim of the investigator is a fuller knowledge or understanding of the subject under study, rather than any practical application thereof.

(*b*) Applied research is considered normally to follow basic research, but may not be separable from the related basic research; it attempts to advance the "state of the art," and to determine and expand the potentialities of new scientific discoveries or improve-

ments in technology, materials, processes, methods, devices, and techniques. Applied research does not include any such efforts when principally aimed at specific articles or services to be offered for sale.

Development

Development is design and experimental work leading to proof of workability. Development is the systematic use of scientific knowledge which is directed toward the production of, or improvements in, useful products to meet specific performance requirements, but exclusive of manufacturing and production engineering. The objective of development is to produce pilot models, pilot-production processes, or operable "breadboard" devices in order to demonstrate technical feasibility and prove principles of operation.

Engineering

Engineering refers to the application of available technology in making, using, and selling products. It is defined as the technical effort applied, after feasibility and principles of operation have been demonstrated, to the design of products that can be manufactured and sold, or to the design of processes (not equipment) for producing such products.

Research, development, and engineering inherently form a continuum; many technical projects are a mixture of those three efforts; and it is frequently difficult to segregate them. Engineering is the most inclusive term since it deals with the technical information needed to make, sell, and use products. If in the conduct of that mission it is necessary to obtain data available in no other way, it is permissible—indeed mandatory—that the responsible engineer initiate action for research or development work to obtain the data. This, however, is not general.

Returning to Figure 1, we see that it illustrates four levels of

technical effort. The fourth is represented by the block entitled Central Research Laboratories. What then might be the mission of the organization represented by the block termed Central Research and Engineering? The remainder of this paper is concerned mainly with that aspect of our operations.

The figure for total technical effort which we publish represents the cost of research, development, and engineering done by the four levels to which I have referred. In 1959, the figure was about $31 million.

Central Research and Engineering

The official statement of the mission and functions of Central Research and Engineering follows:

(*A*) The function of Central Research and Engineering, and the responsibility of its head, Vice President, R&E, is the optimization of the company's total technical effort. This emphasizes particularly the business aspects, interdivisional R&D matters, the general management of all CR&E work and coordination of Central Research Laboratories (CRL) work with divisions and Central Staff.

(*B*) In some detail, the functions of CR&E are to:

(*1*) Formulate technical policies;
(*2*) Comprehend technical requirements and opportunities;
(*3*) Plan and authorize long range central technical efforts to fill needs;
(*4*) Coordinate technical activities so that
  (*a*) Divisions will do research necessary in their areas
  (*b*) CRL will concentrate on new research areas of great specific or general importance;
(*5*) Review and revise 1–4 as necessary;
(*6*) Acquire needed technical information;
(*7*) Assure communication of technical information across TI;
(*8*) Protect TI technical information;

(*9*) Comprehend the needs of all TI's technical people and formulate policies aimed at optimizing their productivity.

In summary, the principal objective of Central Research and Engineering is to optimize our research and engineering effort. A very major factor in that optimization is Central Research Laboratories.* We have, however, eight research departments of roughly equivalent status, one in each of four product divisions and four in the Central Research Laboratories.

Central Research Laboratories

Central Research Laboratories provides the scientific basis for the company to enter new businesses by operating outside the areas of current interest of any of the research departments of the product divisions. This has not always been so. A little more than a year ago, it was the function of Central Research Laboratories to perform research *in support of* the product divisions *as well as outside of* their present areas of interests, but this is no longer true. CRL is busy now finishing up research within the present areas of interests of the research departments of the product divisions preparatory to devoting itself principally to entirely new areas.

The official corporate policy with regard to Central Research Laboratories follows:

(*A*) It is the function of Central Research Laboratories to be the central research and development operating group of TI. It is headed by a director who is Assistant Vice President and Director of Research. He reports to the Vice President, R&E. The director has the responsibility of managing activities essential to the successful performance of research and development in a central laboratories organization, and to gather needed scientific information wherever it may be found. Much of the research is charac-

* Headed by Dr. Gordon Teal, Director of CRL and Assistant Vice President.

terized by high technical risk and long time scale, and all of it is estimated to be of great importance.

(*B*) It is intended that CRL objectives be as follows:

(*1*) Provide adequate scientific and technological bases (emphasizing the solution of critical problems rather than full development) for entering new businesses;
(*2*) Act as technical staff to Vice President, Research and Engineering, President, Central Staff, and division personnel, providing scientific and technological intelligence necessary for sound planning;
(*3*) Provide scientific talent and unique facilities for effective attack on unexpected technical problems of unusual difficulty and great importance;
(*4*) Employ people of high potential, unusual talent and a broad range of abilities in a wide spectrum of scientific disciplines;
(*5*) Maintain an industrial scientific community in which creativity, cross-stimulation, and steady growth of capabilities are fostered.

(*C*) It is our specific intention that

(*1*) CRL devote a considerable amount, probably as high as 60–75% of its effort to a limited number (possibly fewer than 15—maybe more than 25) of "Major-Directed Projects" thought to be of great scientific importance and which —if successful—will be of major importance to the company.
  (*a*) These projects are to be a concerted effort headed by a single project leader having responsibility for the success of the project as well as successful transfer of the technology and/or knowledge to a product division.
  (*b*) The project leader is to have authority for running his project. It must be recognized that in many cases work will have to be done on subprojects subject only to budgetary control.

(2) Arrangements shall be made for the most effective means of transfer of the technology and for its earliest practical exploitation, that is, after
  (a) Solution of critical problems requiring CRL attention.
  (b) Determination of division or other organization to receive results and its ability to exploit them.
  (c) Training and/or transfer of critical technical people. These may be product division people transferred to CRL to work in the project for awhile or CRL people who have become deeply involved in the project and wish to continue with it.

(3) CRL research should be daring rather than pedantic. Full recognition is to be given to the inherently low probability of producing results of major specific importance to the company. Negative results may represent as good work on the part of research people as positive results even though undoubtedly disappointing to all. The earliest possible appropriate action on such negative results should, of course, be taken.

(4) It is obvious that CRL contribution is somewhat proportional to the number of such "Major-Directed Projects" completed successfully. Success on as few as one major project per year could be good performance.

(5) CRL may divert as much as 5% of its effort to curiosity oriented investigative projects of limited scope.

(6) CRL should devote 25–40% of its effort to "Long-Term Exploratory Projects" limited in many cases only by initial selection and assignment to such work of outstandingly talented individuals whose interests lie within areas of science and technology that seem relevant to TI's present or future business. Work of this class is visualized as an important source of
  (a) The scientific and technological background of our business.
  (b) Original inspiration for "Major Directed Project."

(*7*) CRL should communicate technical information vigorously, broadly, and quickly, frequently informally to all parts of TI.

(*8*) CRL should emphasize the responsibility of each TI individual, regardless of organizational rank, to aggressively seek out information he needs in the interest of solving company problems and to influence others to take action or cooperate in action being taken in directions that he considers to be in the company interest.

As stated before, the mission of Central Research and Engineering is to optimize RD&E. The objective is not to eliminate duplication, but to control it. A certain amount of duplication is necessary to foster communications. Rather than entirely eliminate duplication, we prefer to eliminate marginal projects and marginal aspects of even the best projects.

Control is accomplished largely through meetings of our Technical Coordinating Group consisting of the eight heads of the research departments, the Patent Counsel, Administrative Director of Central Research and Engineering, and the two senior research executives of the company: Dr. Teal, and myself. We meet every two months and review formal plans, review facilities, and set the basis for policies.

Current Planning and Cost Control

I mentioned that when our plans for 1959 were made we resolved "never again." Early this fall when we started putting together our annual plan, we applied a doctrine of "corner-stake planning." In short, we recorded a few basic outlines of our plan, a few limiting dimensions, and resisted any temptation for more elaboration.

Our central R&D plan was built on two principles: (*a*) think our projects through very carefully and completely; and (*b*) define authority and responsibility—principally the deployment of people—in very simple but strong overall terms.

Two activities mentioned in the official policy of Central Research Laboratories are major-directed projects and long-term exploratory projects. The first is a project requiring large—or small—scale effort, but aimed at a critical problem which, when solved, permits the company to enter (or continue in) a field with high expectation of profit.

A *major-directed project* has the following characteristics:

(*A*) *Large market:* Research must be in an area and contribute to a project for which the market for a successful product is large, and so obviously large as to obviate a formal market survey.

(*B*) *Advanced technology:* A project must provide technology which is either "first or foremost" or both. If neither, there is limited chance of putting the company in a dominant highly profitable position as a result of the project—*no matter how successful.*

(*C*) *Management concurrence.* A project to be a major-directed project must have the enthusiastic concurrence of a major *line* executive; the President or a division manager. This is necessary to assure that the results of the project—if successful—will be put to use.

(*D*) *Exploitable by company.* A project must be such that the company *can* and *will* exploit any technical advantage resulting. It should "fit" the company capabilities in *marketing, manufacturing,* and *finance.*

(*E*) *Relation to overall company objectives.* The major-directed project must be clearly related to overall company objectives, *and shown repeatedly to be so related.*

The end result—when fully exploited—of a project of this class may make contributions to: (*A*) a radically new business, such as transistors in 1952; (*B*) a totally new product, such as silicon transistors in 1954 or high purity silicon in 1956; (*C*) protecting an important product position; (*D*) extending the profitable life of a product or service by patentable improvements or new techniques. A proposal form for a major-directed project is shown in Figure 2.

1 January 1960

TI-FUNDED RESEARCH PROGRAM - 1960
CENTRAL RESEARCH LABORATORIES

TITLE: GALLIUM ARSENIDE DEVICES AND MATERIALS

ANNUAL EXPENDITURE (Est. 1960):

PROFESSIONAL MAN YEARS (Est. 1960):

PROJECT INITIATED:

TOTAL COST TO DATE:

PRINCIPAL INVESTIGATORS:

Project Manager,
Section Head, Device Technology

Section Head, Exploratory Chemistry

Member of Technical Staff

Member of Technical Staff

PAST ACHIEVEMENTS:

OBJECTIVE AND APPROACH:

CAPITAL EQUIPMENT:

EXPENDITURES - Man Months/K Dollars

1956:	1960(Est:	) (Act:			)
1957:		1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.
1958:	EST.				
1959:	ACT.				

1961	1962	1963	1964	1965	1966	1967	1968	1969	1970

Fig. 2. Typical major-directed project proposal.

Long-term exploratory projects are those which advance the scientific and technologic background of the business. This type of work comes close to being pure research and is at least as important as major-directed projects because it often—and we would hope nearly always—leads to major-directed projects.

We sell research services to the government or others *only* when a recognized company objective is best forwarded by such sale. In most cases, such objectives are to "set up" the later sale of an expected product; or to establish "need to know" in an important area.

As of January 1, 1960, CRL had eleven major-directed projects and about the same number of long-term exploratory projects. However, we plan and state our plan in terms of number of people deployed.

Cost control in our Central Research and Engineering plan was built on the philosophy that the principal constituent of the cost is people without whom no building is needed, no capital equipment required, and no material is consumed.

We set goals for the total number of people directly on the projects and the total number in the overhead area. Then we look back historically to determine usage of materials and supplies.

We put together an overall plan illustrated in Figures 3 and 4. Figure 5 is the summary which we presented to the President, Chairman of the Board, and Vice Presidents who were elated with the simplicity of the plan, if not entirely enchanted with the content. Figures 6 and 7 present summary data on major-directed, and long-term exploratory projects which constitute, respectively, two-thirds and one-third of the work load of Central Research Laboratories.

In reporting costs to the President, we report graphically the total cost of the Central Research and Engineering activity against our plan as shown in Figure 8. If the dollar number is close to the plan, nobody pays much attention to it and we concentrate on the technical results. If the dollar figure is pretty far off for several months running, an examination is made into the reason therefor

		No. Of People 12/31/59 And Through 1960	Dollars (000's) Spent In 1959 (est.)	Total Expected Dollars Year Of 1960
LABOR	MATERIALS DEPT.	XX	$ XX	$ XX
	S. S. P.	XX	XX	XX
	D S & E S	XX	XX	XX
	DEVICES	XX	XX	XX
	THERMOELECTRICS	XX	XX	XX
	MODEL SHOP	XX	–	–
	GLASS SHOP	XX	–	–
	TOTAL DIRECT LABOR	XX	$ XX	$ XX
DIRECT MATERIAL			$ XX	$ XX
	TOTAL DL & DM		$ XX	$ XX
TECHNICAL DEPT. OVERHEAD			XX.X	XX.X
	TOTAL DL, DM & O H		$XX.X	$ XX.X

Fig. 3. DL, DM, and technical department OH–CRL. (1960 CR&E–CRL profit plan.)

		No. Of People 12/31/59 And Through 1960	Dollars (000's) Spent In 1959 (est.)	Total Expected Dollars Year Of 1960
TECHNICAL DEPTS. DL, DM & OH		XX	$XX.X	$XX.X
PERSONNEL, PATENTS & ADMINISTRATION	GEN. ADMINISTRATION	XX		$XX.X
	PURCHASING	XX		XX.X
	TECHNICAL INFORMATION	XX		XX.X
	PRINT CONTROL	XX	$XX.X	XX.X
	INST. REPAIR & MAINT.	XX		XX
	DRAFTING	XX		X.X
	MAINTENANCE DEPT.	XX		XX.X
	PERSONNEL	XX	XX	XX
	PATENTS *	XX	XX	XX
	CR & E STAFF	XX		
	TOTAL	XX	$XX	$XX.X
TOTAL CRE & CRL EXPENDITURE		XX	$XX.X	$XX.X

* 2 PEOPLE ADDED IN 2ND. QUARTER IN 1960

Fig. 4. DL, DM, and OH–CR&E and CRL. (1960 CR&E–CRL profit plan.)

(inevitably, it's because too many or too few people have been deployed).

General management of the company sees a total number representing the expenditures of Central Research for the month

	No. Of People 12/31/59 And Through 1960	Dollars (000's) Spent In 1959 (est.)	Total Expected Dollars Year Of 1960
TOTAL CR&E & CRL EXPENDITURES	XX	$XX.X	$XX.X
OUTSIDE RESEARCH, CONTRIBUTIONS AND GRANTS		XX	XX
CONTINGENCY			XX
GRAND TOTAL — CR&E & CRL		$XX.X	$XX.X
RECOVERY			
MLO ON GOVERNMENT CONTRACTS		XX	XX
CHARGES TO DIVISIONS		XX	XX
GSI		XX	XX
COMMERCIAL CHARGES		XX.X	XX
TOTAL RECOVERY		$XX.X	$XX
NET CR&E & CRL EXPENDITURE		XX.X	XX.X

Fig. 5. Total and net expenditures. (1960 CR&E–CRL profit plan.)

	Project	Proj. Mgr	Dept.	MRD	DRD	SSP	DSES	CRL Total	Division Interest	Div. Tot.	Project Totals
1	GaAs HIGH TEMP. TRANST. RECT.	JOHNSON	DRD	XX	XX	.X		XX.X	SC		XX.X
2	SILICON TRANS. RELIABILITY	POGH	DRD	X	XX.X	X		XX.X	SC		XX.X
3		JENSON	DSES				XX	XX	GID		XX
4		REMBERT	MRD	X				X	SC		X
5		RONAH	DRD	XX.X	XX	.X		XX	ALL	*XX	XX
6		VON HEIFETZ	DRD		X			X	APP	*X	X
7		STEINMEIR	MRD	X.X	.X	.X		X.X	APP		X.X
8		BEINHOFEN	DRD		X.X			X.X	APP		X.X
9		OLIVIER	DSES				XX	XX	APP	*X	XX
10		McKENNON	DSES	.X	X	X	XX	XX.X	APP & GID		XX.X
11		EINSTROM	MRD	X.X				X.X	M/C	*X	X.X
	LEGEND:	TOTALS °		XX	XX.X	X.X	XX	XXX.X		*XX	XXX.X
	°EXCLUSIVE OF GLASS AND MODEL SHOPS	TOTALS ° CRL ≠ DIV		XX	XX.X	X.X	XX				XXX.X

*WORKING IN CRL, DIVISION PARTICIPATION

Fig. 6. Central Research Laboratories. Projects 1960. I. CRL major-directed projects.

	Project	% Prod. Orient.	Project Head	Dept.	MRD	DRD	SSP	DSES	CRL Totals	Division Interest
1	TRANSDUCERS	XX	SORRELS	DRD		X			X	ALL
2	SIC & BORON	XX	SONGH	MRD	X	X			X	SC
3		XX	BENSON	DSES				XX	XX	APP & GID
4		XX	SOUTHERN	SSP			X		X	
5		XX	EINSTROM	MRD	X.X				X.X	APP & M/C
6		XX	HART	SSP			X.X		X.X	SC & APP
7		XX	JOHNSON	RES. ASSO.					X	ALL
8		XX	HOLDER	MRD	X.X				X.X	M/C
9		XX	WIENER	SSP			X.X		X.X	SC & M/C
10		X	BULL	DRD		X.X			X.X	
11		X	JOHNSON	DRD		X			X	
12		X	KANT	MRD	X				X	
13		X	JUDGE	MRD	X				X	
14		X	BRIGGS	SSP			X.X		X.X	
* EXCLUSIVE OF GLASS & MODEL SHOP			TOTALS *		XX	X.X	XX.X	XX	XX.X	

Fig. 7. Central Research Laboratories. Projects 1960. I. CRL long-term exploratory projects.

under consideration. The Vice President, Research and Engineering sees a report that breaks down this number into labor, material, and overhead, into cost versus plan for the eleven major-directed projects, and analyzes the overhead. Further detail is unnecessary unless the figures are grossly different from plans or expectations.

This beautiful simplicity is, however, too good to be true. In the review of our annual plans, we found that the categories major-directed projects and long-term exploratory projects are not sufficiently inclusive. We found that we have projects of major importance to the company which cannot be termed "direct." They are investigative, not exploratory. We know where they are, but we do not choose to set up objectives very tightly. We may

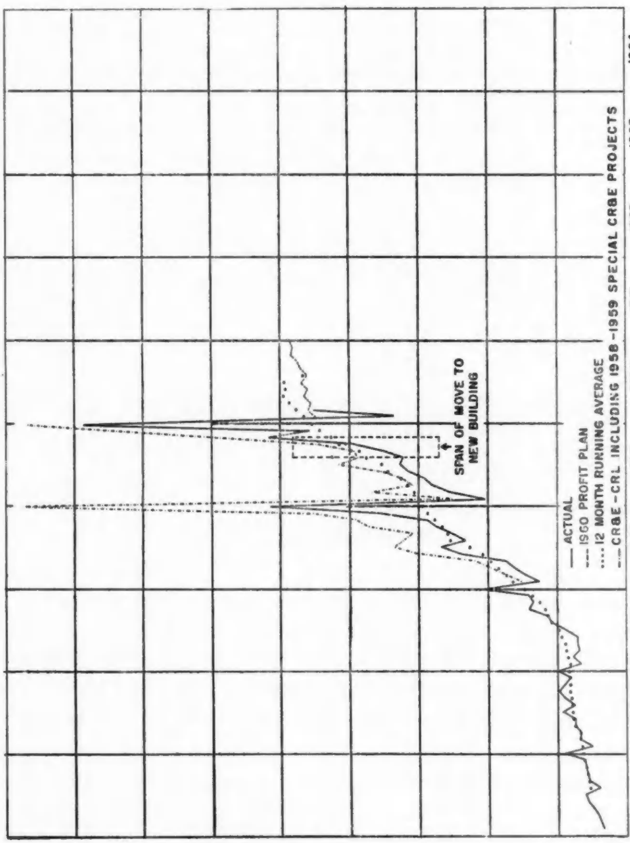

Fig. 8. Central research and engineering. CRL expenditures 1955 to date. (CRL, only 1955–57; CR&E–CRL, 1958–60.)

	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970
Major Exploratory Projects														
Major-Directed Projects														
Long-Term Exploratory Projects														
Directed Projects														
Patents														
Personnel														
Administration														
Total People														
DL & OH														
Material														
Total														
Recovery														
Total CR&E Cost To T.I.														

Fig. 9. Ten-year corner-stake plan.

add a class "Major Investigative Projects" but here too the simplicity is not to go unblemished because we have projects that are directed, important, and that we want to continue but that certainly do not qualify as major. We might ultimately therefore include another category making four or possibly more classes of CRL work. Thus starts the cycle of complexity again.

Our probable manner of handling planning in the future will be a combination of:

(*A*) Corner-take planning "the principal outlining dimensions of our plan" as shown in Figure 9 to include: (*1*) Scientific work controlled by deployment of people to: (*a*) long-term exploratory projects, (*b*) major exploratory projects, (*c*) major-directed projects, (*d*) projects of specific importance, and (*e*) short-term investigative (legalized "bootlegging"); (*2*) material, estimated in dollars by historic precedent; (*3*) supplies, estimated in dollars by historic precedent; (*4*) overhead, controlled by deployment of people.

(*B*) Continuous planning: (*1*) Projects and areas of interest are laid out in general (as shown on Figure 2) as far into the future

as we are able to estimate and summarized on a ten-year scale. (*2*) Incremental plan changes (plus or minus) for short-term aspects are filed and accumulated until a major change or presentation is called for. (*3*) When a plan is called for presentation, we "close the books" and present it. (*4*) The annual operating plan is contained in and a part of the "Corner-Stake-Plan," which is inherently a long-range plan.

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